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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a **PROVISIONAL APPLICATION FOR PATENT** under 37 CFR 1.53 (b)(2).

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INVENTOR(s) / APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
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TITLE OF THE INVENTION (280 characters max)

AUTHENTICATING AN AUTHENTIC ARTICLE AND PROTECTING AUTHENTICITY THEREOF USING SPECTRAL IMAGING AND ANALYSIS

CORRESPONDENCE ADDRESS

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ENCLOSED APPLICATION PARTS *(check all that apply)*

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METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No

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Respectfully submitted,

SIGNATURE _____ Date November 25, 2003

REGISTRATION NO. (*if appropriate*) 25,457

TYPED or PRINTED NAME SOL SHEINBEIN

☐ Additional inventors are being named on separately numbered sheets attached hereto

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APPLICATION FOR PATENT

Inventor: Danny S. MOSHE

Title: AUTHENTICATING AN AUTHENTIC ARTICLE AND PROTECTING AUTHENTICITY THEREOF USING SPECTRAL IMAGING AND ANALYSIS

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to methods and devices for authenticating authentic articles, and more particularly, to a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis.

The field of article authentication, including methods, devices, and systems, for authenticating authentic articles, and for protecting authenticity of an authentic article, is relatively well developed and sophisticated. Unfortunately, however, technologies and activities used for counterfeiting and/or illegally producing, distributing or circulating, using, and/or selling, authentic articles, have similarly become well developed and quite sophisticated, especially on a global international basis. There is a strong need for 'keeping at least one step ahead' of such developed and sophisticated counterfeit and/or illegal technologies and activities.

There is thus a need for, and it would be highly advantageous to have a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis.

SUMMARY OF THE INVENTION

The present invention relates to a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis.

Thus, according to the present invention, there is provided a method for authenticating an authentic article having an authentication mark, comprising the steps of: (a) acquiring a set of spectral images of at least a part of the authentication mark; (b) forming a set of single-authentication mark spectral fingerprint data from the set of acquired spectral images of the imaged authentication mark; (c) identifying at least one spectral shift in the set of single-authentication mark spectral fingerprint data associated with the imaged authentication mark, for forming an intra-authentication mark physicochemical region group including a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted relative to the value of each corresponding data element in each remaining sub-set in the same intra-authentication mark physicochemical region group; (d) forming a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark, by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group of the imaged authentication mark; and (e) comparing and matching values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

According to another aspect of the present invention, there is provided a method for protecting authenticity of an authentic article, comprising incorporating onto or into the authentic article an authentication mark which includes a particulate form of a pigmented ink, wherein particles of the particulate pigmented ink are uniquely and unambiguously characterizable by at least one type of a morphologically dependent physicochemical property when subjected to a method of spectral imaging comprising the steps of: (i) acquiring a set of spectral images of each of a number of the particles of the particulate

pigmented ink; (ii) forming a set of single-particle spectral fingerprint data from each set of acquired spectral images of each imaged particle; (iii) identifying at least one spectral shift in each set of single-particle spectral fingerprint data associated with each imaged particle, for forming an intra-particle region group featuring a plurality of sub-sets of intra-particle spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted relative to the value of each corresponding data element in each remaining sub-set in the same intra-particle region group; (iv) forming a set of intra-particle physicochemical properties and characteristics data relating to each imaged particle, by performing pattern recognition and classification analysis on the intra-particle region group of the imaged particle; (v) using a plurality of the sets of the intra-particle physicochemical properties and characteristics data of the number of particles of the particulate pigmented ink, for identifying intra-particle morphological or geometrical distribution of the morphologically dependent physicochemical property of the particulate pigmented ink included in the authentication mark; and (vi) comparing and matching the intra-particle morphological or geometrical distribution to a reference intra-particle morphological or geometrical distribution of the morphologically dependent physicochemical property of the particulate pigmented ink included in the authentication mark, thereby authenticating the authentic article.

According to another aspect of the present invention, there is provided a device for authenticating an authentic article having an authentication mark, comprising: (a) an illumination energy source, for generating electromagnetic radiation; (b) illumination energy source optics, operatively positioned relative to the illumination energy source, for selecting a range of the electromagnetic radiation and for focusing the selected range of electromagnetic radiation; (c) a first bundle of a plurality of flexible fiber optic tubes, operatively positioned relative to the output of the illumination energy source optics, for receiving and transmitting the focused selected range of electromagnetic radiation onto at least a part of the authentication mark of the authentic article; (d) a second bundle of a plurality of flexible fiber optic tubes, operatively connected to the first bundle of flexible fiber optic tubes, for receiving and transmitting emission beams of electromagnetic radiation emitted by the at least part of the authentication mark; (e) a rotating optical disc spectrometer including a plurality of disc shaped optical filters positioned on a platform and a rotator mechanism for rotating the platform, the rotating optical disc spectrometer is

operatively positioned relative to the output of the second bundle of flexible fiber optic tubes, for selectively optically filtering the authentication mark emission beams transmitted by the second bundle of flexible fiber optic tubes; (f) a detector, operatively positioned relative to the rotating optical disc spectrometer, for detecting the optically filtered authentication mark emission beams; and (g) a data/information processing and analyzing unit, operatively connected to the illumination energy source and to the detector, for processing and analyzing data and information associated with the focused selected range of electromagnetic radiation of step (c) and the detected authentication mark emission beams of step (f), such that there is acquiring therefrom a set of spectral images of the at least a part of the authentication mark which are used for forming, comparing, and matching, values of elements in a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

Implementation of a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis, of the present invention, involves performing steps and sub-steps in a manner selected from the group consisting of manually, semi-automatically, fully automatically, and a combination thereof, and involves operation of components, mechanisms, and elements, in a manner selected from the group consisting of manual, semi-automatic, fully automatic, and a combination thereof. Moreover, according to actual steps and sub-steps, components, mechanisms, and elements, used for implementing a particular embodiment of the disclosed invention, steps and sub-steps are performed by using hardware, software, or an integrated combination thereof, and, components, mechanisms, and elements, operate by using hardware, software, or an integrated combination thereof.

In particular, software used for implementing the present invention features operatively connected and functioning written or printed data, in the form of software programs, software routines, software sub-routines, software symbolic languages, software code, software instructions or protocols, or a combination thereof. Hardware used for implementing the present invention features operatively connected and functioning electronic components and elements, in the form of a computer chip, an integrated circuit,

an electronic circuit, an electronic sub-circuit, a hard-wired electrical circuit, or a combination thereof, involving digital and/or analog operations. Accordingly, an integrated combination of (1) software and (2) hardware, used for implementing the present invention, features an integrated combination of (1) operatively connected and functioning written or printed data, in the form of software programs, software routines, software sub-routines, software symbolic languages, software code, software instructions or protocols, or a combination thereof, and (2) operatively connected and functioning electronic components and elements, in the form of a computer chip, an integrated circuit, an electronic circuit, an electronic sub-circuit, a hard-wired electrical circuit, or a combination thereof, involving digital and/or analog operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative description of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the present invention. In this regard, no attempt is made to show structural details of the present invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice. In the drawings:

FIG. 1 is a schematic diagram illustrating an exemplary preferred embodiment of the device for authenticating an authentic article having an authentication mark, using spectral imaging and analysis, in accordance with the present invention;

FIG. 2 is a schematic diagram illustrating the step of identifying spectral shifts in intra-authentication mark spectral imaging data representative of the exemplary authentication mark, (am^*), of the authentic article of FIG. 1, in accordance with the present invention; and

FIG. 3 is a schematic diagram illustrating an exemplary intra-authentication mark physicochemical properties and characteristics data map, PPCD Map [am^*], of the

exemplary imaged part of authentication mark, (am^*), of the authentic article of FIG. 1, generated from the exemplary set of the set of intra-authentication mark physicochemical properties and characteristics data, PPCD[am^* : PC-R_j ($ppcd_j$)], formed from the spectral imaging data of FIG. 2, in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis.

The generalized method for authenticating an authentic article having an authentication mark, of the present invention, features the main steps of: (a) acquiring a set of spectral images of at least a part of the authentication mark; (b) forming a set of single-authentication mark spectral fingerprint data from the set of acquired spectral images of the imaged authentication mark; (c) identifying at least one spectral shift in the set of single-authentication mark spectral fingerprint data associated with the imaged authentication mark, for forming an intra-authentication mark physicochemical region group including a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted relative to the value of each corresponding data element in each remaining sub-set in the same intra-authentication mark physicochemical region group; (d) forming a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark, by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group of the imaged authentication mark; and (e) comparing and matching values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

The present invention also provides a corresponding specific method for protecting authenticity of an authentic article, which features the step of incorporating onto or into the

authentic article an authentication mark which includes a particulate form of a pigmented ink, wherein particles of the particulate pigmented ink are uniquely and unambiguously characterizable by at least one type of a morphologically dependent physicochemical property when subjected to a method of spectral imaging comprising the steps of: (i) acquiring a set of spectral images of each of a number of the particles of the particulate pigmented ink; (ii) forming a set of single-particle spectral fingerprint data from each set of acquired spectral images of each imaged particle; (iii) identifying at least one spectral shift in each set of single-particle spectral fingerprint data associated with each imaged particle, for forming an intra-particle region group featuring a plurality of sub-sets of intra-particle spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted relative to the value of each corresponding data element in each remaining sub-set in the same intra-particle region group; (iv) forming a set of intra-particle physicochemical properties and characteristics data relating to each imaged particle, by performing pattern recognition and classification analysis on the intra-particle region group of the imaged particle; (v) using a plurality of the sets of the intra-particle physicochemical properties and characteristics data of the number of particles of the particulate pigmented ink, for identifying intra-particle morphological or geometrical distribution of the morphologically dependent physicochemical property of the particulate pigmented ink included in the authentication mark; and (vi) comparing and matching the intra-particle morphological or geometrical distribution to a reference intra-particle morphological or geometrical distribution of the morphologically dependent physicochemical property of the particulate pigmented ink included in the authentication mark, thereby authenticating the authentic article.

The corresponding device for authenticating an authentic article having an authentication mark, of the present invention, features the main components: (a) an illumination energy source, for generating electromagnetic radiation; (b) illumination energy source optics, operatively positioned relative to the illumination energy source, for selecting a range of the electromagnetic radiation and for focusing the selected range of electromagnetic radiation; (c) a first bundle of a plurality of flexible fiber optic tubes, operatively positioned relative to the output of the illumination energy source optics, for receiving and transmitting the focused selected range of electromagnetic radiation onto at least a part of the authentication mark of the authentic article; (d) a second bundle of a

plurality of flexible fiber optic tubes, operatively connected to the first bundle of flexible fiber optic tubes, for receiving and transmitting emission beams of electromagnetic radiation emitted by the at least part of the authentication mark; (e) a rotating optical disc spectrometer including a plurality of disc shaped optical filters positioned on a platform and a rotator mechanism for rotating the platform, the rotating optical disc spectrometer is operatively positioned relative to the output of the second bundle of flexible fiber optic tubes, for selectively optically filtering the authentication mark emission beams transmitted by the second bundle of flexible fiber optic tubes; (f) a detector, operatively positioned relative to the rotating optical disc spectrometer, for detecting the optically filtered authentication mark emission beams; and (g) a data/information processing and analyzing unit, operatively connected to the illumination energy source and to the detector, for processing and analyzing data and information associated with the focused selected range of electromagnetic radiation of step (c) and the detected authentication mark emission beams of step (f), such that there is acquiring therefrom a set of spectral images of the at least a part of the authentication mark which are used for forming, comparing, and matching, values of elements in a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

The method for authenticating an authentic article having at least one authentication mark, the corresponding method for protecting authenticity of an authentic article, and the corresponding device for implementing thereof, using spectral imaging and analysis, of the present invention, are based on, but not limited to, the main aspect of novelty and inventiveness of identifying relatively small shifts in spectral parameters, in particular, intensity or amplitude, and energy (in terms of wavelength, frequency, or wavenumber), of electromagnetic radiation emitted by at least a part of an authentication mark, in a set of single-authentication mark spectral fingerprint data formed from acquired spectral images of the imaged authentication mark.

An intra-authentication mark physicochemical region group is formed therefrom, which includes a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted (on the order of about 0.1 % or ppt (parts per thousand) level) relative to the value

of each corresponding data element in each remaining sub-set in the same intra-authentication mark physicochemical region group. A set of intra-authentication mark physicochemical properties and characteristics data, for example, physicochemical properties and characteristics of the ink, and, physicochemical properties and characteristics of the substrate (for example, paper of paper currency, natural or synthetic material of a product label) of the ink, relating to the imaged authentication mark is formed by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group of the imaged authentication mark. Then, there is comparing and matching values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

The present invention has several beneficial and advantageous features and characteristics, which are based on, in addition to, or a consequence of, the above described main aspect of novelty and inventiveness.

First, the present invention is highly accurate (typically, on the order of ppm (parts per million) level of accuracy per authenticated article) and is highly precise. Accordingly, by implementing the present invention, there is unambiguously authenticating an authentic article having at least one authentication mark, in a highly accurate and reproducible manner. Moreover, in the event that an 'unauthentic' article having an unauthentic (fake or counterfeit) authentication mark is subjected to the method of the present invention, the method will provide an unambiguous and accurate mismatch between values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged 'unauthentic' authentication mark and corresponding values of reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby unambiguously determining the non-authenticity of an unauthentic article.

Second, the present invention is applicable for 'multi-level' authenticating an authentic article having an authentication mark including a first level of 'overt' features and characteristics which are visually recognizable, detectable, and authenticatable, by a human, and verifiable by using the present invention, and a second level of 'covert' features

and characteristics which are visually recognizable, detectable, and authenticatable, by only a spectral imaging device operated according to the method of the present invention.

Third, the present invention is generally applicable to a wide variety of different types of authentic articles. For example, paper forms of monetary currency, bank notes, and checks; plastic card forms of monetary currency, such as credit cards; paper or plastic card forms of identification, such as birth certificates, ID cards, drivers licenses, passports, and visas; and natural or synthetic material forms of a product label, such as of clothing, audio-visual products, expensive equipment, and equipment subjected to international trade restrictions.

Fourth, the present invention is generally applicable to a wide variety of different types of authentication marks. For example, authentication marks made up of a single type of an ink, or made up of a variety of different types of inks. Ink used for printing authentication marks may include an aqueous or organic solvent base, and include one or more pigments in a completely dissolved non-solid form, or in a solid (micron sized fine powder) form. Authentication marks may be of a single color or of a variety of several different colors.

Authentication marks, as viewed by unaided human eyes, and touched by a human hand, may feature an essentially flat and smooth two-dimensional pattern or design, or, feature an elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Authentication marks may be any of a wide variety of different types of watermarks, where a watermark is generally known in the art as being a clearly perceptive and/or a translucent pattern or design impressed onto or embedded into a substrate, such as paper, and visible to unaided human eyes when the substrate is held to ordinary ambient light. A translucent watermark transmits light, but in a manner which causes sufficient diffusion to eliminate perception of at least a part of a distinct image of the watermark.

A particular authentication mark may be a single essentially flat and smooth two-dimensional pattern or design, or, a single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively, a particular authentication mark may be a plurality or composite (physical overlay) of two or more single essentially flat and smooth two-dimensional patterns or designs, or, a plurality or composite (physical overlay)

of two or more single elevated or contoured and rough, three-dimensional patterns or designs each characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively, a particular authentication mark may be a combination (physical overlay) of at least one single essentially flat and smooth two-dimensional pattern or design, and at least one single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure.

Additionally, authentication marks may include one or more components which exhibit fluorescent and/or phosphorescent properties, characteristics, and behavior, when illuminated by different types of light, such visible, ultra-violet, and infrared, types of light.

Fifth, the present invention is commercially applicable and is well suitable for real time applications and situations involving the need for quickly authenticating an authentic article. This aspect is especially important for business and commercial applications, involving persons and institutions handling, processing, and authenticating, large volumes of authentic articles on a day to day basis, during which the total time required for authenticating such large volumes should be minimized in order to preserve the capability of performing day to day business and commerce in a quick and efficient manner.

Sixth, the present invention can be implemented as part of a global international secure authentication network. For example, in the case of paper currency, the present invention can be implemented at each of a large number of local and/or regional banks for authenticating paper currency during bank to consumer transactions and/or bank to bank transactions, respectively, taking place in a single country or in different countries, and can additionally be implemented at each of a number of international banks and/or government entities for authenticating large amounts of the paper currency used in international transactions. Any number of the local, regional, and international, banks and/or institutions can be linked into a single secure authentication network.

Seventh, the present invention can be implemented for providing sophisticated, accurate, and precise, traceability to authentic articles, as well as to unauthentic (fake or counterfeit) articles, involving tracking or tracing paths of circulation (procurement, distribution, and/or use), including sources and destinations, of authentic articles, and/or of unauthentic articles. This aspect of the present invention is especially useful to the field of international law enforcement, involved with forensics and other legal matters pertaining to

illegal procurement, distribution, and/or use, of authentic articles and/or unauthentic articles. Relatedly, the present invention can be applied for detecting, analyzing, and classifying, authentic articles, and/or unauthentic articles, which have authentication marks that feature unknown physicochemical properties and characteristics.

Based upon the above indicated main aspect of novelty and inventiveness, and, beneficial and advantageous features and characteristics, the present invention successfully overcomes various limitations, and widens the scope, of presently known methods and devices for authenticating authentic articles, and for protecting the authenticity thereof.

It is to be understood that the present invention is not limited in its application to the details of the order or sequence, and number, of steps and sub-steps of operation or implementation of the method, or to the details of type, composition, construction, arrangement, order, and number, of the components and elements of the device, set forth in the following description and accompanying drawings. For example, the following description refers to authenticating an authentic article having a single authentication mark, in order to illustrate implementation of the present invention. In practice, often, an authentic article has several authentication marks, including the possibility of each authentication mark differing in physicochemical properties and characteristics. Additionally, for example, the following description refers to spectral imaging and analysis, in general, in order to illustrate implementation of the present invention. It is to be clearly understood that the method and device of the present invention can be implemented according to different specific types of spectral imaging and analysis, for example, hyper-spectral imaging and analysis, focus-fusion spectral imaging and analysis, modifications thereof, and combinations thereof, well known in the art and technology of spectral imaging and analysis. Accordingly, the present invention is capable of other embodiments or of being practiced or carried out in various ways. Although steps and components similar or equivalent to those described herein can be used for practicing or testing the present invention, suitable steps and components are described herein.

It is also to be understood that unless otherwise defined, all technical and scientific words, terms, and/or phrases, used herein have either the identical or similar meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Phraseology, terminology, and, notation, employed herein are for the purpose of

description and should not be regarded as limiting. Additionally, as used herein, the term 'about' refers to ± 10 % of the associated value.

Steps, sub-steps, components, elements, operation, and implementation of a method for authenticating an authentic article having at least one authentication mark, a corresponding method for protecting authenticity of an authentic article, and a corresponding device for implementing thereof, using spectral imaging and analysis, according to the present invention, are better understood with reference to the following description and accompanying drawings. Throughout the following description and accompanying drawings, same reference numbers refer to same components or same elements.

In the following description of the method and device of the present invention, included are main or principal steps and sub-steps, and main or principal devices, mechanisms, components, and elements, needed for sufficiently understanding proper 'enabling' utilization and implementation of the disclosed method and device. Accordingly, description of various possible required and/or optional preliminary, intermediate, minor, steps, sub-steps, devices, mechanisms, components, and/or elements, which are readily known by one of ordinary skill in the art, and/or which are available in the prior art and technical literature relating to spectral imaging and analysis, fiber optic imaging technology, and printing and ink technologies relating to paper currency manufacture, product labeling, and authentication marking, are at most only briefly indicated herein.

Immediately following, there is first provided description of a preferred embodiment of the generalized method and corresponding generalized device for authenticating an authentic article having at least one authentication mark, using spectral imaging and analysis. Thereafter, is provided description of a preferred embodiment of a corresponding specific method for protecting authenticity of an authentic article, using spectral imaging and analysis.

In **Step (a)** of the method for authenticating an authentic article having an authentication mark, of the present invention, there is acquiring a set of spectral images of at least a part of the authentication mark.

Reference is now made to the drawings, wherein FIG. 1 is a schematic diagram illustrating an exemplary preferred embodiment of the device, hereinafter, referred to as spectral imaging device **10**, of the present invention, for authenticating an authentic article,

hereinafter, referred to as authentic article **12**, having an authentication mark, hereinafter, referred to as authentication mark **14**, and also by the notation of (am*), using spectral imaging and analysis.

The present invention is generally applicable to a wide variety of different types of an authentic article **12**. For example, authentic article **12** can be a paper form of monetary currency, a bank note, or a check; a plastic card form of monetary currency, such as a credit card; a paper or plastic card form of identification, such as a birth certificate, an ID card, a drivers license, a passport, or a visa; or, a natural or synthetic material form of a product label, such as of an article of clothing, an audio-visual product, a piece of expensive equipment, or a piece of equipment subjected to international trade restrictions.

The present invention is generally applicable to authentic article **12** having any of a wide variety of different types of an authentication mark **14**. For example, authentication mark **14** may be made up of a single type of an ink, or made up of a variety of different types of inks. Ink used for printing authentication mark **14** may include an aqueous or organic solvent base, and include one or more pigments in a completely dissolved non-solid form, or in a solid (micron sized fine powder) form. Authentication mark **14** may be of a single color or of a variety of several different colors.

Authentication mark **14**, as viewed by unaided human eyes, and touched by a human hand, may feature an essentially flat and smooth two-dimensional pattern or design, or, feature an elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Authentication mark **14** may be any of a wide variety of different types of watermarks, where a watermark is a clearly perceptive and/or a translucent pattern or design impressed onto or embedded into a substrate, such as paper, and visible to unaided human eyes when the substrate is held to ordinary ambient light. Authentication mark **14** in the form of a translucent watermark transmits light, but in a manner which causes sufficient diffusion to eliminate perception of at least a part of a distinct image of the watermark.

Authentication mark **14** may be a single essentially flat and smooth two-dimensional pattern or design, or, a single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively, authentication mark **14** may be a

plurality or composite (physical overlay) of two or more single essentially flat and smooth two-dimensional patterns or designs, or, a plurality or composite (physical overlay) of two or more single elevated or contoured and rough, three-dimensional patterns or designs each characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively, authentication mark **14** may be a combination (physical overlay) of at least one single essentially flat and smooth two-dimensional pattern or design, and at least one single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure.

Additionally, authentication mark **14** may include one or more components which exhibit fluorescent and/or phosphorescent properties, characteristics, and behavior, when illuminated by different types of light, such visible, ultra-violet, and infrared, types of light.

In FIG. 1, spectral imaging device **10** is operative for generating, detecting, acquiring, measuring, processing, analyzing, and indicating/displaying, spectral imaging data and information, during real time or at least during near real time. For performing these tasks, spectral imaging device **10** features the main components: (a) an illumination energy source **16**, (b) illumination energy source optics **18**, (c) a first bundle **20** of a plurality of flexible fiber optic tubes **22**, (d) a second bundle **24** of a plurality of flexible fiber optic tubes **26**, (e) a rotating optical disc spectrometer **28** including (i) a plurality of disc shaped optical filters **30**, (ii) a platform **32**, and (iii) a rotator mechanism **34**, (f) a detector **36**, and (g) a data/information processing and analyzing unit **38**. Optionally, spectral imaging device **10** additionally includes (h) a display/indicator unit **40**.

Illumination energy source **16** is for generating electromagnetic radiation **50**. Preferably, electromagnetic radiation **50** is in the form of light, selected from the group consisting of polychromatic light, monochromatic light, poly- or multi-monochromatic light, and, combinations thereof. An exemplary polychromatic light is white light. An exemplary monochromatic light is selected from the group consisting of visible (VIS) spectrum monochromatic light, in the range of 350 - 750 nm, such as red light, blue light, or green light, and, invisible spectrum monochromatic light, such as ultra-violet (UV) light, in the range of 100 - 350 nm, or infrared (IR) light, in the range of 750 nm - 0.5 mm. An exemplary poly- or multi-chromatic light is a combination of a plurality of at least two different previously listed exemplary monochromatic lights.

Illumination energy source optics **18**, is operatively positioned relative to illumination energy source **16**, and is for selecting a range of electromagnetic radiation **50** and for focusing the selected range of electromagnetic radiation **50** which is ultimately incident upon at least a part of authentication mark **14** of authentic article **12**. Illumination energy source optics **18** includes, for example, (i) an optical filtering mechanism **52**, and (ii) a focusing mechanism **54**. Optical filtering mechanism **52**, for example, a rotatable set of several optical filters, is for selectively filtering electromagnetic radiation **50** according to a pre-determined range of a single wavelength, or, according to a pre-determined range of a plurality of wavelengths, of electromagnetic radiation **50** exiting illumination energy source optics **16**, for forming filtered electromagnetic radiation **56**. Focusing mechanism **54**, for example, a lens, is for focusing filtered electromagnetic radiation **56**, for forming focused electromagnetic radiation **58**, which is transmitted into first bundle **20** of flexible fiber optic tubes **22**.

As illustrated in FIG. 1, spectral imaging device **10** includes a single Illumination energy source **16**, along with appropriately positioned optical filtering mechanism **52** and focusing mechanism **54**, for transmitting electromagnetic radiation into first bundle **20** of flexible fiber optic tubes **22**. In an alternative embodiment of the present invention, spectral imaging device **10** includes a plurality of two or more separately operable or multiplexed individual illumination energy sources **16**, along with an appropriately positioned focusing mechanism **54**, without inclusion of optical filtering mechanism **52**, for transmitting focused electromagnetic radiation **58**, of different individual wavelengths, into first bundle **20** of flexible fiber optic tubes **22**.

First bundle **20** of a plurality of flexible fiber optic tubes **22**, is operatively positioned relative to the output of illumination energy source optics **18**, and is for receiving and transmitting the focused selected range of electromagnetic radiation **50**, in particular, focused electromagnetic radiation **58**, onto at least a part of authentication mark **14** of authentic article **12**. Second bundle **24** of a plurality of flexible fiber optic tubes **26**, is operatively connected to the first bundle **20** of flexible fiber optic tubes **22**, and is for receiving and transmitting emission beams **60** of electromagnetic radiation emitted by the illuminated part of authentication mark **14**.

In an exemplary preferred embodiment of the present invention, first bundle **20** of flexible fiber optic tubes **22** and second bundle **24** of flexible fiber optic tubes **26**, are operatively connected in the form of an extendable 'pen'. For example, as illustrated in FIG. 1, wherein a flexible fiber optic housing **62** houses first and second bundles **20** and **24**, respectively, of the fiber optic tubes, and a firm end piece **64** is for enabling sturdy manual holding and manipulating of fiber optic housing **62**. This type of construction enables quick and efficient directing and aiming of the opening of fiber optic housing **62**, and therefore of fiber optic tubes **22** for transmitting focused electromagnetic radiation **58** onto the at least part of authentication mark **14** of authentic article **12**, and of fiber optic tubes **26** for receiving emission beams **60** of electromagnetic radiation emitted by the illuminated part of authentication mark **14** of authentic article **12**.

Rotating optical disc spectrometer **28** includes a plurality of disc shaped optical filters **30**, positioned on a platform **32** and a rotator mechanism **34** for rotating platform **32**. Rotating optical disc spectrometer **28** is operatively positioned relative to the output of second bundle **24** of fiber optic tubes **26**, and is for selectively optically filtering the authentication mark emission beams **60** transmitted by second bundle **24** of fiber optic tubes **26**. Disc shaped optical filters **30**, as indicated in FIG. 1 by the exemplary plurality of five optical filters, f_1, f_2, f_3, f_4, and f_5, are each used for optically filtering a pre-determined bandwidth or wavelength range of authentication mark emission beams **60** transmitted by second bundle **24** of fiber optic tubes **26**, for forming optically filtered transmitted authentication mark emission beams **66**.

Detector **36** is operatively positioned relative to rotating optical disc spectrometer **28**, and is for detecting optically filtered authentication mark emission beams **66**. Detector **36** is, for example, a CCD type of detecting device.

Data/information processing and analyzing unit **38** is operatively connected to illumination energy source **16** and to detector **36**, and is for processing and analyzing data and information associated with electromagnetic radiation **50** generated by illumination energy source **16**, focused electromagnetic radiation **58** exiting focusing mechanism **54**, and optically filtered authentication mark emission beams **66** detected by detector **36**. From these sources of spectral data and information, there is acquiring and analyzing sets of spectral images of the illuminated part of authentication mark **14**.

As described below, in **Steps (b) - (e)**, the acquired spectral images are used for forming, comparing, and matching, values of elements in a set of intra-authentication mark physicochemical properties and characteristics data relating to imaged authentication mark **14** to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of authentic article **12**, thereby authenticating authentic article **12**.

Optionally, spectral imaging device **10** additionally includes a display/indicator unit **40**, which is operatively connected to data/information processing and analyzing unit **38**, and is for displaying and/or indicating various forms of input and output data and information relating to overall control and operation of spectral imaging device **10**, including, for example, the authentication results generated by data/information processing and analyzing unit **38**.

Thus, completion of **Step (a)** results in acquiring a set of spectral images representative of at least a part of authentication mark, (am^*), **14** of authentic article **12**. The set of spectral images is stored in a single-authentication mark spectral image database.

As previously stated above, the description herein refers to spectral imaging and analysis, in general, in order to illustrate implementation of the present invention. It is to be clearly understood that the method and device of the present invention can be implemented according to different specific types of spectral imaging and analysis, for example, hyper-spectral imaging and analysis, focus-fusion spectral imaging and analysis, modifications thereof, and combinations thereof, well known in the art and technology of spectral imaging and analysis.

In **Step (b)**, there is forming a set of single-authentication mark spectral fingerprint data from the set of acquired spectral images of the imaged authentication mark of the authentic article.

Step (b) is performed by using data/information processing and analyzing unit **38** of spectral imaging device **10**, and the data is stored in a single-authentication mark spectral fingerprint database.

With reference to FIG. 1, for authentication mark, (am^*), **14** of authentic article **12**, the set of spectral images, acquired and stored by operating spectral imaging device **10**, is used for forming a set of single-authentication mark spectral fingerprint data, $F(am^*)$. The

set of single-authentication mark spectral fingerprint data, $F(am^*)$, is characterized by a single-authentication mark spectral fingerprint spectrum, $S(am^*)$, **70**, featuring intensity or amplitude, $A(am^*)$, of the energy of optically filtered authentication mark emission beam **66**, herein, for brevity, referred to as emitted energy, $E(am^*)$, **66**, plotted as a function of emitted energy, $E(am^*)$, **66** detected by detector **36** during imaging authentication mark **14** (am^*) by spectral imaging device **10**. Preferably, emitted energy, $E(am^*)$, **66** is expressed in terms of wavelength, frequency, or wavenumber, of electromagnetic radiation, such as fluorescent or phosphorescent light, emitted by authentication mark, (am^*), **14** of authentic article **12**. This data is stored in a single-authentication mark spectral fingerprint database.

In **Step (c)**, there is identifying at least one spectral shift in the set of single-authentication mark spectral fingerprint data associated with the imaged authentication mark, for forming an intra-authentication mark physicochemical region group including a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, such that the value of at least one selected data element in each sub-set is shifted relative to the value of each corresponding data element in each remaining sub-set in the same intra-authentication mark physicochemical region group.

This spectral shift identification step is performed on the set of single-authentication mark spectral fingerprint data, $F(am^*)$, characterized by single-authentication mark spectral fingerprint spectrum, $S(am^*)$, **70**, for forming an intra-authentication mark physicochemical region group of a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, relating to and representative of authentication mark, (am^*), **14** of authentic article **12**. **Step (c)** is performed by using data/information processing and analyzing unit **38** of spectral imaging device **10**, and the data is stored in a intra-authentication mark physicochemical region group database.

The identification procedure involves analyzing the plurality of acquired spectral images for those particular spectral images which only 'slightly' differ by relatively small shifts in the value of the emitted energy, $E(am^*)$, **66**, and/or, only 'slightly' differ by relatively small shifts in the value of the intensity or amplitude, $A(am^*)$, of emitted energy, $E(am^*)$, **66**, detected by detector **36** of spectral imaging device **10**. Preferably, the identification procedure involves analyzing the plurality of spectral images for those

particular spectral images which only slightly differ by relatively small shifts in the value of the emitted energy, $E(am^*)$, **66**, in terms of a shift in wavelength, frequency, or, wavenumber, of fluorescent or phosphorescent light emitted by a the imaged part of authentication mark, (am^*), **14**, and detected by spectral imaging device **10**.

Specifically, there is identifying at least one spectral shift, s_i, in each set of single-authentication mark spectral fingerprint data, $F(am^*)$, associated with the imaged part of authentication mark, (am^*), **14**, for forming an intra-authentication mark physicochemical region group, herein, referred to as $PC\text{-}RG(am^*)$, featuring a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, herein, referred to as $FP(am^*, PC\text{-}R_j)$, where the value of at least one selected data element, for example, emitted energy, $E(am^*)$, **66**, and/or, intensity or amplitude, $A(am^*)$, of emitted energy, $E(am^*)$, **66**, in each sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, is shifted relative to the value of each corresponding data element in each remaining sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_k)$, for k not equal to j, in the same intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$.

Each sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, is characterized by an intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_j)$, featuring intensity or amplitude, $A(am^*, PC\text{-}R_j)$ of emitted energy, $E(am^*, PC\text{-}R_j)$, **66**, plotted as a function of affected energy, emitted energy, $E(am^*, PC\text{-}R_j)$, **66**, detected during imaging authentication mark, (am^*), **14**, by spectral imaging device **10**.

$PC\text{-}R_j$, for j = 1 to J, and $PC\text{-}R_k$, for k not equal to j, different sub-sets of intra-authentication mark spectral fingerprint pattern data in the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$, are intra-authentication mark physicochemical region group sub-set identifiers, used for distinguishing among the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, and $FP(am^*, PC\text{-}R_k)$, associated with the same set of single-authentication mark spectral fingerprint data, $F(am^*)$. This classification enables performing next **Step (d)** of

forming a set of intra-authentication mark physicochemical properties and characteristics data from the intra-authentication mark physicochemical region group, PC-RG(am^*), featuring the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j).

Existence of at least one spectral shift, s_i, in a given set of single-authentication mark spectral fingerprint data, F(am^*), associated with the imaged part of authentication mark, (am^*), **14**, is due to the local, intra-authentication mark, variation, heterogeneity, or fluctuation, of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, of the imaged part of authentication mark, (am^*), **14**.

This intra-authentication mark variation, heterogeneity, or fluctuation, of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, of the imaged part of authentication mark, (am^*), **14**, corresponds to a plurality of at least two different physicochemical region types, each associated with different physicochemical properties and characteristics data, in the intra-authentication mark physicochemical region group, PC-RG(am^*), of the imaged part of authentication mark, (am^*), **14**. This variable or heterogeneous physicochemical phenomenon corresponds to focused electromagnetic radiation **58**, which is transmitted through fiber optic tubes **22** and incident upon the at least part of authentication mark **14** of authentic article **12** (FIG. 1), being affected slightly differently by each intra-authentication mark physicochemical region type, of the imaged part of authentication mark, (am^*), **14** of authentic article **12**, whereby spectral imaging device **10** is used for accurately and reproducibly detecting and analyzing this phenomenon, for the purpose of highly accurately and unambiguously authenticating authentic article **12**.

The above described process of identifying spectral shifts is clearly illustrated in FIG. 2, a schematic diagram illustrating the step of identifying spectral shifts in intra-authentication mark spectral imaging data representative of authentication mark, (am^*), **14** of authentic article **12**. For example, in the set of single-authentication mark spectral fingerprint data, F(am^*), of the imaged part of authentication mark, (am^*), **14**, characterized by single-authentication mark spectral fingerprint spectrum, S(am^*), **70**,

shown in FIG. 1, there is identifying at least one spectral shift, s_i, in the value of at least one selected data element, for example, emitted energy, $E(am^*, PC\text{-}R_j)$, **66**, and/or, intensity or amplitude, $A(am^*, PC\text{-}R_j)$ of emitted energy, $E(am^*, PC\text{-}R_j)$, **66**, where such potentially identified spectral shift(s), s_i, are referenced in FIG. 2 by the four directional crossed arrows **80**, for forming intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**.

In this illustrative example, for the imaged part of authentication mark, (am^*), **14**, intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82** features four sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_1)$, $FP(am^*, PC\text{-}R_2)$, $FP(am^*, PC\text{-}R_3)$, and $FP(am^*, PC\text{-}R_4)$, where each sub-set, $FP(am^*, PC\text{-}R_j)$, is characterized by a corresponding intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_1)$, $S(am^*, PC\text{-}R_2)$, $S(am^*, PC\text{-}R_3)$, and $S(am^*, PC\text{-}R_4)$, respectively, featuring intensity or amplitude, $A(am^*, PC\text{-}R_1)$, $A(am^*, PC\text{-}R_2)$, $A(am^*, PC\text{-}R_3)$, and $A(am^*, PC\text{-}R_4)$, of emitted energy **66**, $E(am^*, PC\text{-}R_1)$, $E(am^*, PC\text{-}R_2)$, $E(am^*, PC\text{-}R_3)$, and $E(am^*, PC\text{-}R_4)$, respectively, plotted as a function of emitted energy **66**, $E(am^*, PC\text{-}R_1)$, $E(am^*, PC\text{-}R_2)$, $E(am^*, PC\text{-}R_3)$, and $E(am^*, PC\text{-}R_4)$, respectively, referenced by **70A**, **70B**, **70C**, and **70D**, respectively.

In FIG. 2, three spectral shifts, s_1, s_2, and s_3, are shown identified, whereby the value of at least one selected data element, for example, emitted energy, $E(am^*, PC\text{-}R_j)$, **66**, in each sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, is shifted relative to the value of each corresponding data element, $E(am^*, PC\text{-}R_k)$, in each remaining sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_k)$, for k not equal to j, in the same intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**. In this particular illustrative example, the first sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_1)$, characterized by the corresponding intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_1)$, referenced by **70A**, is shown as a baseline used for identifying and illustrating the three spectral shifts, s_1, s_2, and s_3, in the value of at least one selected

data element, in this case, $E(am^*, PC\text{-}R_1)$, from the value of each corresponding data element, in this case, $E(am^*, PC\text{-}R_2)$, $E(am^*, PC\text{-}R_3)$, and $E(am^*, PC\text{-}R_4)$, respectively, in the three remaining sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_2)$, $FP(am^*, PC\text{-}R_3)$, and $FP(am^*, PC\text{-}R_4)$, respectively, where each remaining sub-set is characterized by the corresponding intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_2)$, $S(am^*, PC\text{-}R_3)$, and $S(am^*, PC\text{-}R_4)$, respectively, referenced by **70B**, **70C**, and **70D**, respectively.

Specifically, as shown in FIG. 2, spectral shift, s_1, corresponds to a shift in the value of the emitted energy data element, $E(am^*, PC\text{-}R_j)$, from the baseline value of emitted energy data element, $E_0(am^*, PC\text{-}R_1)$, in the first sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_1)$, characterized by the first intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_1)$, **70A**, to a shifted lower value of emitted energy data element, $E_1(am^*, PC\text{-}R_2)$, in the second sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_2)$, characterized by the second intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_2)$, **70B**. As shown in FIG. 2, the value of emitted energy E_1 is less than the baseline value of emitted energy E_0.

Spectral shift, s_2, corresponds to a shift in the value of the emitted energy data element, $E(am^*, PC\text{-}R_j)$, from the baseline value of emitted energy data element, $E_0(am^*, PC\text{-}R_1)$, in the first sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_1)$, characterized by the first intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_1)$, **70A**, to a shifted lower value of emitted energy data element, $E_2(am^*, PC\text{-}R_3)$, in the third sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_3)$, characterized by the third intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_3)$, **70C**. As shown in FIG. 2, the value of emitted energy E_2 is less than the value of emitted energy E_1.

Spectral shift, s_3, corresponds to a shift in the value of the emitted energy data element, $E(am^*, PC\text{-}R_j)$, from the baseline value of emitted energy data element, $E_0(am^*, PC\text{-}R_1)$, in the first sub-set of intra-authentication mark spectral fingerprint pattern data,

$FP(am^*, PC\text{-}R_1)$, characterized by the first intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_1)$, **70A**, to a shifted higher value of emitted energy data element, $E_3(am^*, PC\text{-}R_4)$, in the fourth sub-set of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_4)$, characterized by the fourth intra-authentication mark spectral fingerprint pattern spectrum, $S(am^*, PC\text{-}R_4)$, **70D**. As shown in FIG. 2, the value of emitted energy E_3 is greater than the baseline value of emitted energy E_0, greater than the value of emitted energy E_1, and greater than the value of emitted energy E_2.

In **Step (d)**, there is forming a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark, by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group of the imaged authentication mark.

This step is performed for forming a set of intra-authentication mark physicochemical properties and characteristics data relating to and representative of the imaged part of authentication mark, (am^*), **14**, of authentic article **12**. **Step (d)** is performed by using data/information processing and analyzing unit **38** of spectral imaging device **10**, and the data is stored in an intra-authentication mark physicochemical properties and characteristics data database.

The imaged part of authentication mark, (am^*), **14**, of authentic article **12**, being spectrally imaged and analyzed for exhibiting spectral shifts, s_i, exhibits intra-authentication mark variation, heterogeneity, or fluctuation, of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, such that there exists a corresponding plurality of at least two different physicochemical region types, each associated with different physicochemical properties and characteristics data, in the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$, of the imaged part of authentication mark, (am^*), **14**. Accordingly, the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, are used for forming the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**, as described in preceding **Step (c)**. In **Step (d)**, for the imaged part of authentication mark, (am^*), **14**, of authentic article **12**, the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*,$

PC-R_j), featured in the intra-authentication mark physicochemical region group, PC-RG(am^*) **82**, are correlated with a corresponding plurality of intra-authentication mark physicochemical region types, PC-R_j, for j = 1 to J different types of intra-authentication mark physicochemical regions identified in, or assigned to, the imaged part of authentication mark, (am^*), **14**, by performing pattern recognition and classification analysis.

Intra-authentication mark physicochemical region type, PC-R_j, corresponds to the intra-authentication mark physicochemical region group sub-set identifier, PC-R_j, used in **Step (c)** for distinguishing among the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j), associated with the same set of single-authentication mark spectral fingerprint data, F(am^*), as shown in FIG. 2.

Each intra-authentication mark physicochemical region type, PC-R_j, is associated with a different set of physicochemical properties and characteristics data, herein, referred to as PPCD, of the imaged part of authentication mark, (am^*), **14**. PPCD varies throughout the imaged part of authentication mark, (am^*), **14**, in accordance with variation of the associated intra-authentication mark physicochemical region type, PC-R_j. Due to the local, intra-authentication mark, variation, heterogeneity, or fluctuation of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, of the imaged part of authentication mark, (am^*), **14**, the focused electromagnetic radiation **58**, which is transmitted through fiber optic tubes **22** and incident upon the at least part of authentication mark **14** of authentic article **12** (FIG. 1), is affected slightly differently by each intra-authentication mark physicochemical region type, of the imaged part of authentication mark, (am^*), **14** of authentic article **12**.

This intra-authentication mark physicochemical phenomenon existing during imaging part of authentication mark, (am^*), **14** of authentic article **12**, enables forming intra-authentication mark physicochemical region group, PC-RG(am^*) **82**, in **Step (c)**, featuring the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j), where the value of at least one selected data element in each sub-set, FP(am^*, PC-R_j), is shifted relative to the value of each corresponding data element in each remaining sub-set, FP(am^*, PC-R_k), for k not equal to j, in the same intra-authentication

mark physicochemical region group, PC-RG(am^*) **82**, as illustratively exemplified in FIG. 2 for the imaged part of authentication mark, (am^*), **14**.

Accordingly, in **Step (d)**, for the imaged part of authentication mark, (am^*), **14**, there is forming a set of intra-authentication mark physicochemical properties and characteristics data, herein, referred to as PPCD[am^* : PC-R_j ($ppcd_j$)], for j = 1 to J different intra-authentication mark physicochemical region types, PC-R_j, of the imaged part of authentication mark, (am^*), **14** of authentic article **12**, by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group, PC-RG(am^*) **82**, of the imaged part of authentication mark, (am^*), **14**, featuring the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j), exhibiting spectral shifts, s_i, associated with the same set of single-authentication mark spectral fingerprint data, F(am^*).

For example, with reference to FIG. 2, for the imaged part of authentication mark, (am^*), **14** of authentic article **12** featuring variation, heterogeneity, or fluctuation, of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, of the imaged part of authentication mark, (am^*), **14**, the plurality of four sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_1), FP(am^*, PC-R_2), FP(am^*, PC-R_3), and FP(am^*, PC-R_4), where each sub-set, FP(am^*, PC-R_j), is characterized by the corresponding intra-authentication mark spectral fingerprint pattern spectrum, S(am^*, PC-R_1) **70A**, S(am^*, PC-R_2) **70B**, S(am^*, PC-R_3) **70C**, and S(am^*, PC-R_4) **70D**, respectively, exhibiting spectral shifts, s_1, s_2, and s_3, in emitted energy **66**, E(am^*, PC-R_j), used for forming the intra-authentication mark physicochemical region group, PC-RG(am^*) **82**, in accordance with preceding **Step (c)**, are correlated with the four corresponding different intra-authentication mark physicochemical region types, PC-R_1, PC-R_2, PC-R_3, and PC-R_4, respectively, of the imaged part of authentication mark, (am^*), **14** of authentic article **12**.

Accordingly, for the imaged part of authentication mark, (am^*), **14**, featuring, for example, four different intra-authentication mark physicochemical region types, PC-R_j, for j = 1 to 4, the set of intra-authentication mark physicochemical properties and

characteristics data is written as: PPCD[am^* : PC-R_j ($ppcd_j$)], for j = 1 to 4, and the complete set of intra-authentication mark physicochemical properties and characteristics data becomes: PPCD[am^* : PC-R_1 ($ppcd_1$); PC-R_2 ($ppcd_2$); PC-R_3 ($ppcd_3$); PC-R_4 ($ppcd_4$)], as referenced by **90** in the upper part of FIG. 3. The complete set of intra-authentication mark physicochemical properties and characteristics data can be used for generating an exemplary intra-authentication mark physicochemical properties and characteristics data map, PPCD Map [am^*] **92**, of the imaged part of authentication mark, (am^*), **14**, as illustrated in the bottom part of FIG. 3.

Pattern recognition and classification in **Step (d)** of the present invention can be performed by using any number of a variety of known methods. Preferably, **Step (d)** of the present invention is performed by using the same methodology of pattern recognition and classification described in the same applicant disclosures of U.S. Patent No. 6,438,261, U.S. Patent No. 6,091,843, and U.S. Patent No. 5,880,830, the teachings of each of which are incorporated by reference for all purposes as if fully set forth herein.

For performing the pattern recognition and classification analysis, there is applying one or more image analysis algorithms, such as detection, pattern recognition and classification, and/or decision image analysis algorithms, to the intra-authentication mark physicochemical region group, PC-RG(am^*) **82**, of the imaged part of authentication mark, (am^*), **14**, featuring a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j), exhibiting spectral shifts, s_i, associated with the same set of single-authentication mark spectral fingerprint data, F(am^*).

The plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, FP(am^*, PC-R_j), are analyzed by relating and correlating intra-authentication mark spectral information and parameters of (i) pixel intensity, (ii) signal-to-noise ratio (S/N), (iii) image sharpness, (iv) spectral distances (in particular, distances between pre-determined individual neighboring pixels and/or between pre-determined groups of neighboring pixels), and, (v) spectral fingerprints (pattern of peaks, troughs, and shifts, in the curves of authentication mark emission spectra) associated with distinct spectral emission patterns of the imaged part of authentication mark, (am^*), **14**, that is, spectral fingerprints in the corresponding plurality of intra-authentication mark spectral fingerprint

pattern spectrums, $S(am^*, PC\text{-}R_j)$ for example, as illustrated in FIG. 2, to empirically determined intra-authentication mark physicochemical property and characteristics relating to the variation, heterogeneity, or fluctuation, of (i) physicochemical properties and characteristics of the ink, and/or, of (ii) physicochemical properties and characteristics of the substrate of the ink, of the imaged part of authentication mark, (am^*), **14**.

Calibration data of standard samples of authentic article **12** with known, or unknown, but measurable, intra-authentication mark physicochemical property and characteristics, are used as part of the pattern recognition and classification image analysis. This includes performing pattern recognition and classification with respect to intra-authentication mark physicochemical region groups, $PC\text{-}RG(am^*)$ **82**, of the imaged part of authentication mark, (am^*), **14**, each having a plurality of different intra-authentication mark physicochemical region types, $PC\text{-}R_j$.

Step (d) includes relating the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, exhibiting spectral shifts, s_i, associated with the same set of single-authentication mark spectral fingerprint data, $F(am^*)$ in the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**, of the imaged part of authentication mark, (am^*), **14**, of authentic article **12**, to empirically determined sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, exhibiting spectral shifts, s_i, associated with the same set of single-authentication mark spectral fingerprint data, $F(am^*)$ in the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**, of the imaged part of authentication mark, (am^*), **14**, of authentic article **12**. The empirically determined sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, are obtained and stored from spectral imaging a statistically meaningful representative calibration or standard reference sample of authentic article **12** having authentication mark, (am^*), **14**, featuring known variation, heterogeneity, or fluctuation, of physicochemical properties and characteristics of the ink, and/or, of physicochemical properties and characteristics of the substrate of the ink, of the authentication mark, (am^*), **14**.

Examples of specific detection, pattern recognition and classification, and/or decision algorithms suitable for image analysis in the method of the present invention are fully described in previously cited U.S. Patent Nos. 6,438,261; 6,091,843; and 5,880,830, and references cited therein, which are incorporated by reference for all purposes as if fully set forth herein. For example, as described by Kettig, R.L. and Landgrebe, D., in "Classification Of Multispectral Image Data By Extraction And Classification Of Homogeneous Objects", *IEEE Transactions on Geoscience Electronics*, Vol. GE14 p. 19 (1976). Alternatively, neural networks are trained, for example, as described by Yu, P., Anastassopoulos, V., and Venetsanopoulos, A. N., "Pattern Classification And Recognition Based On Morphology And Neural Networks", *Can. J. Elect. and Comp. Eng.*, Vol. 17 No. 2 (1992) pp. 58-59 and references cited therein, using the calibration spectral descriptor vectors and spectral types, and, the calibration physicochemical descriptor vectors and physicochemical types, as neural training sets.

The desired relationships between the calibration spectral descriptor vectors and types, and, the calibration physicochemical descriptor vectors and types, are used as trained neural networks, applicable to the plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, $FP(am^*, PC\text{-}R_j)$, exhibiting spectral shifts, s_i, associated with the same set of single-authentication mark spectral fingerprint data, $F(am^*)$ in the intra-authentication mark physicochemical region group, $PC\text{-}RG(am^*)$ **82**, of the imaged part of authentication mark, (am^*), **14**, of authentic article **12**.

In **Step (e)**, there is comparing and matching values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

This step is performed for generating highly accurate and unambiguous results of authentication of authentic article **12**. **Step (e)** is performed by using data/information processing and analyzing unit **38** of spectral imaging device **10**, and the result is stored in data/information processing and analyzing unit **38**. Optionally, the authentication results generated by data/information processing and analyzing unit **38** are displayed and/or

indicated on a display/indicator unit **40**, operatively connected to data/information processing and analyzing unit **38**, as shown in FIG. 1.

In this step, there is comparing and matching values of the elements, PC-R_j ($ppcd_j$), for j = 1 to 4, being PC-R_1 ($ppcd_1$), PC-R_2 ($ppcd_2$), PC-R_3 ($ppcd_3$), and PC-R_4 ($ppcd_4$), in the complete set of intra-authentication mark physicochemical properties and characteristics data, PPCD[am^* : PC-R_j ($ppcd_j$)], as referenced by **90** in the upper part of FIG. 3, relating to and representative of the imaged part of authentication mark, (am^*), **14**, of authentic article **12**, to values of the corresponding reference (^{R}) elements, PC-R_j $(ppcd_j)^R$, for j = 1 to 4, being PC-R_1 $(ppcd_1)^R$, PC-R_2 $(ppcd_2)^R$, PC-R_3 $(ppcd_3)^R$, and PC-R_4 $(ppcd_4)^R$, in the complete reference set of intra-authentication mark physicochemical properties and characteristics data, $PPCD^R$ [am^* : PC-R_j $(ppcd_j)^R$], of the corresponding imaged part of a reference authentication mark, $(am^*)^R$, of authentic article **12**.

For authentication of an authentic article, such as authentic article **12**, according to an established 'authentication' criterion or specification, for example, based on having a pre-determined minimum number of 'matched' values of the data elements during and/or following the comparison of the two sets of intra-authentication mark physicochemical properties and characteristics data, **Step (e)** generates a highly accurate and unambiguous result of authentication of authentic article **12**.

Thus, based on, in addition to, or a consequence of, the above described aspects of novelty and inventiveness, the present invention as illustratively described and exemplified hereinabove, has several beneficial and advantageous features and characteristics.

The present invention is highly accurate (typically, on the order of ppm (parts per million) level of accuracy per authenticated article) and is highly precise. By implementing the present invention, there is unambiguously authenticating an authentic article having at least one authentication mark, in a highly accurate and reproducible manner. In the event that an 'unauthentic' article having an unauthentic (fake or counterfeit) authentication mark is subjected to the method of the present invention, the method will provide an unambiguous and accurate mismatch between values of elements in the set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged 'unauthentic' authentication mark and corresponding values of reference elements in a reference set of intra-authentication mark physicochemical properties and

characteristics data of the authentic article, thereby unambiguously determining the non-authenticity of an unauthentic article.

The present invention is applicable for 'multi-level' authenticating an authentic article having an authentication mark including a first level of 'overt' features and characteristics which are visually recognizable, detectable, and authenticatable, by a human, and verifiable by using the present invention, and a second level of 'covert' features and characteristics which are visually recognizable, detectable, and authenticatable, by only a spectral imaging device operated according to the method of the present invention.

The present invention is generally applicable to a wide variety of different types of authentic articles. For example, paper forms of monetary currency, bank notes, and checks; plastic card forms of monetary currency, such as credit cards; paper or plastic card forms of identification, such as birth certificates, ID cards, drivers licenses, passports, and visas; and natural or synthetic material forms of a product label, such as of clothing, audio-visual products, expensive equipment, and equipment subjected to international trade restrictions.

The present invention is generally applicable to a wide variety of different types of authentication marks. For example, authentication marks made up of a single type of an ink, or made up of a variety of different types of inks. Ink used for printing authentication marks may include an aqueous or organic solvent base, and include one or more pigments in a completely dissolved non-solid form, or in a solid (micron sized fine powder) form. Authentication marks may be of a single color or of a variety of several different colors.

The present invention is applicable to authentication marks, which, as viewed by unaided human eyes, and touched by a human hand, may feature an essentially flat and smooth two-dimensional pattern or design, or, feature an elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Authentication marks may be any of a wide variety of different types of watermarks which are impressed onto or embedded into a substrate, such as paper, of the authentic article, and visible to unaided human eyes when the substrate is held to ordinary ambient light.

The present invention is applicable to a particular authentication mark being a single essentially flat and smooth two-dimensional pattern or design, or, a single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively,

the particular authentication mark may be a plurality or composite (physical overlay) of two or more single essentially flat and smooth two-dimensional patterns or designs, or, a plurality or composite (physical overlay) of two or more single elevated or contoured and rough, three-dimensional patterns or designs each characterized by a three-dimensional morphological or geometrical shape, form, or structure. Alternatively, the particular authentication mark may be a combination (physical overlay) of at least one single essentially flat and smooth two-dimensional pattern or design, and at least one single elevated or contoured and rough, three-dimensional pattern or design characterized by a three-dimensional morphological or geometrical shape, form, or structure.

Additionally, authentication marks may include one or more components which exhibit fluorescent and/or phosphorescent properties, characteristics, and behavior, when illuminated by different types of light, such visible, ultra-violet, and infrared, types of light.

The present invention is commercially applicable and is well suitable for real time applications and situations involving the need for quickly authenticating an authentic article. This aspect is especially important for business and commercial applications, involving persons and institutions handling, processing, and authenticating, large volumes of authentic articles on a day to day basis, during which the total time required for authenticating such large volumes should be minimized in order to preserve the capability of performing day to day business and commerce in a quick and efficient manner.

The present invention can be implemented as part of a global international secure authentication network. For example, in the case of paper currency, the present invention can be implemented at each of a large number of local and/or regional banks for authenticating paper currency during bank to consumer transactions and/or bank to bank transactions, respectively, taking place in a single country or in different countries, and can additionally be implemented at each of a number of international banks and/or government entities for authenticating large amounts of the paper currency used in international transactions. Any number of the local, regional, and international, banks and/or institutions can be linked into a single secure authentication network.

The present invention can be implemented for providing sophisticated, accurate, and precise, traceability to authentic articles, as well as to unauthentic (fake or counterfeit) articles, involving tracking or tracing paths of circulation (procurement, distribution, and/or use), including sources and destinations, of authentic articles, and/or of unauthentic

articles. This aspect of the present invention is especially useful to the field of international law enforcement, involved with forensics and other legal matters pertaining to illegal procurement, distribution, and/or use, of authentic articles and/or unauthentic articles. Relatedly, the present invention can be applied for detecting, analyzing, and classifying, authentic articles, and/or unauthentic articles, which have authentication marks that feature unknown physicochemical properties and characteristics.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.

While the invention has been described in conjunction with specific embodiments and examples thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method for authenticating an authentic article having an authentication mark, comprising the steps of:

(a) acquiring a set of spectral images of at least a part of the authentication mark;

(b) forming a set of single-authentication mark spectral fingerprint data from said set of acquired spectral images of said imaged authentication mark;

(c) identifying at least one spectral shift in said set of single-authentication mark spectral fingerprint data associated with said imaged authentication mark, for forming an intra-authentication mark physicochemical region group including a plurality of sub-sets of intra-authentication mark spectral fingerprint pattern data, such that value of at least one selected data element in each said sub-set is shifted relative to value of each corresponding said data element in each remaining said sub-set in same said intra-authentication mark physicochemical region group;

(d) forming a set of intra-authentication mark physicochemical properties and characteristics data relating to said imaged authentication mark, by performing pattern recognition and classification analysis on said intra-authentication mark physicochemical region group of said imaged authentication mark; and

(e) comparing and matching values of elements in said set of intra-authentication mark physicochemical properties and characteristics data relating to said imaged authentication mark to values of corresponding reference elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

2. A method for protecting authenticity of an authentic article, comprising incorporating onto or into the authentic article an authentication mark which includes a particulate form of a pigmented ink, wherein particles of said particulate pigmented ink are uniquely and unambiguously characterizable by at least one type of a morphologically dependent physicochemical property when subjected to a method of spectral imaging comprising the steps of:

(i) acquiring a set of spectral images of each of a number of said particles of said particulate pigmented ink;

(ii) forming a set of single-particle spectral fingerprint data from each said set of acquired spectral images of each said imaged particle;

(iii) identifying at least one spectral shift in each said set of single-particle spectral fingerprint data associated with each said imaged particle, for forming an intra-particle region group featuring a plurality of sub-sets of intra-particle spectral fingerprint pattern data, where value of at least one selected data element in each said sub-set is shifted relative to value of each corresponding said data element in each remaining said sub-set in same said intra-particle region group;

(iv) forming a set of intra-particle physicochemical properties and characteristics data relating to each said imaged particle, by performing pattern recognition and classification analysis on said intra-particle region group of said imaged particle;

(v) using a plurality of said sets of said intra-particle physicochemical properties and characteristics data of said number of particles of said particulate pigmented ink, for identifying intra-particle morphological or geometrical distribution of said morphologically dependent physicochemical property of said particulate pigmented ink included in said authentication mark; and

(vi) comparing and matching said intra-particle morphological or geometrical distribution to a reference intra-particle morphological or geometrical distribution of said morphologically dependent

physicochemical property of said particulate pigmented ink included in said authentication mark, thereby authenticating the authentic article.

3. A device for authenticating an authentic article having an authentication mark, comprising:

(a) an illumination energy source, for generating electromagnetic radiation;

(b) illumination energy source optics, operatively positioned relative to said illumination energy source, for selecting a range of said electromagnetic radiation and for focusing said selected range of electromagnetic radiation;

(c) a first bundle of a plurality of flexible fiber optic tubes, operatively positioned relative to output of said illumination energy source optics, for receiving and transmitting said focused selected range of electromagnetic radiation onto at least a part of the authentication mark of the authentic article;

(d) a second bundle of a plurality of flexible fiber optic tubes, operatively connected to said first bundle of flexible fiber optic tubes, for receiving and transmitting emission beams of electromagnetic radiation emitted by said at least part of the authentication mark;

(e) a rotating optical disc spectrometer including a plurality of disc shaped optical filters positioned on a platform and a rotator mechanism for rotating said platform, said rotating optical disc spectrometer is operatively positioned relative to output of said second bundle of flexible fiber optic tubes, for selectively optically filtering said authentication mark emission beams transmitted by said second bundle of flexible fiber optic tubes;

(f) a detector, operatively positioned relative to said rotating optical disc spectrometer, for detecting said optically filtered authentication mark emission beams; and

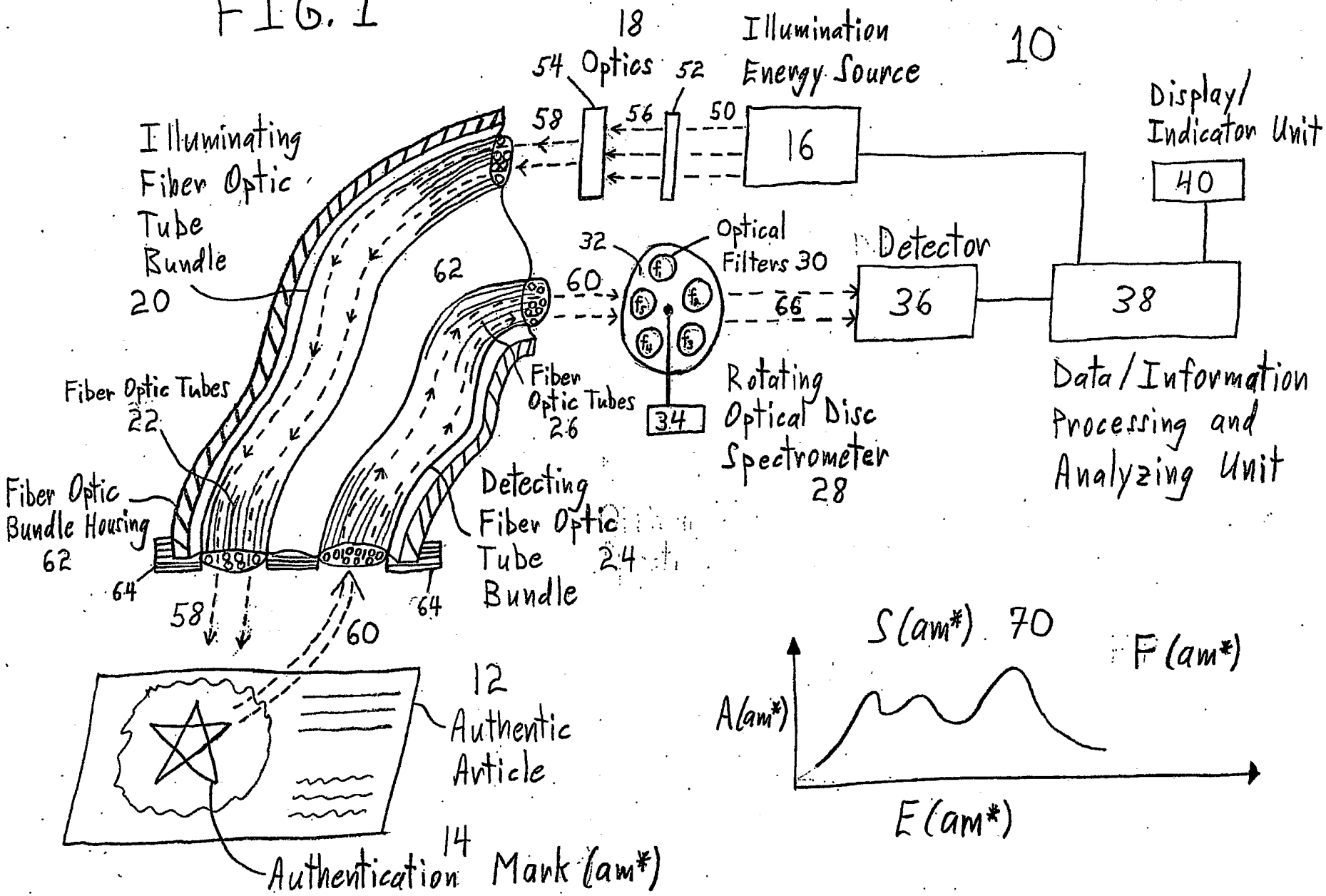
(g) a data/information processing and analyzing unit, operatively connected to said illumination energy source and to said detector, for processing and analyzing data and information associated with said focused selected range of electromagnetic radiation of step (c) and said detected authentication

mark emission beams of step (f), such that there is acquiring therefrom a set of spectral images of said at least a part of the authentication mark which are used for forming, comparing, and matching, values of elements in a set of intra-authentication mark physicochemical properties and characteristics data relating to said imaged authentication mark to values of elements in a reference set of intra-authentication mark physicochemical properties and characteristics data of the authentic article, thereby authenticating the authentic article.

ABSTRACT OF THE DISCLOSURE

Authenticating an authentic article having an authentication mark. Acquiring a set of spectral images of the authentication mark, for forming a set of single-authentication mark spectral fingerprint data (FIG. 1). Identifying at least one spectral shift in the set of single-authentication mark spectral fingerprint data, for forming an intra-authentication mark physicochemical region group including sub-sets of intra-authentication mark spectral fingerprint pattern data, such that data elements in each sub-set are shifted relative to corresponding data elements in remaining sub-sets in the same intra-authentication mark physicochemical region group (FIG. 2). Forming a set of intra-authentication mark physicochemical properties and characteristics data relating to the imaged authentication mark, by performing pattern recognition and classification analysis on the intra-authentication mark physicochemical region group (FIG. 3). Comparing and matching elements in the set of intra-authentication mark physicochemical properties and characteristics data to corresponding reference elements in a reference set of data, thereby authenticating the authentic article.

FIG. 1


18
Illumination Energy Source
10
54 Optics
52
58
56
50
16
Display/ Indicator Unit
40
Illuminating Fiber Optic Tube Bundle
20
62
32
Optical Filters 30
60
Detector
36
38
66
Fiber Optic Tubes
22
Fiber Optic Tubes
26
Rotating Optical Disc Spectrometer
28
34
Data/Information Processing and Analyzing Unit
Fiber Optic Bundle Housing
62
Detecting Fiber Optic Tube Bundle
24
64
58
60
64
12
Authentic Article
14
Authentication Mark (am*)
S(am*) 70
F(am*)
A(am*)
E(am*)

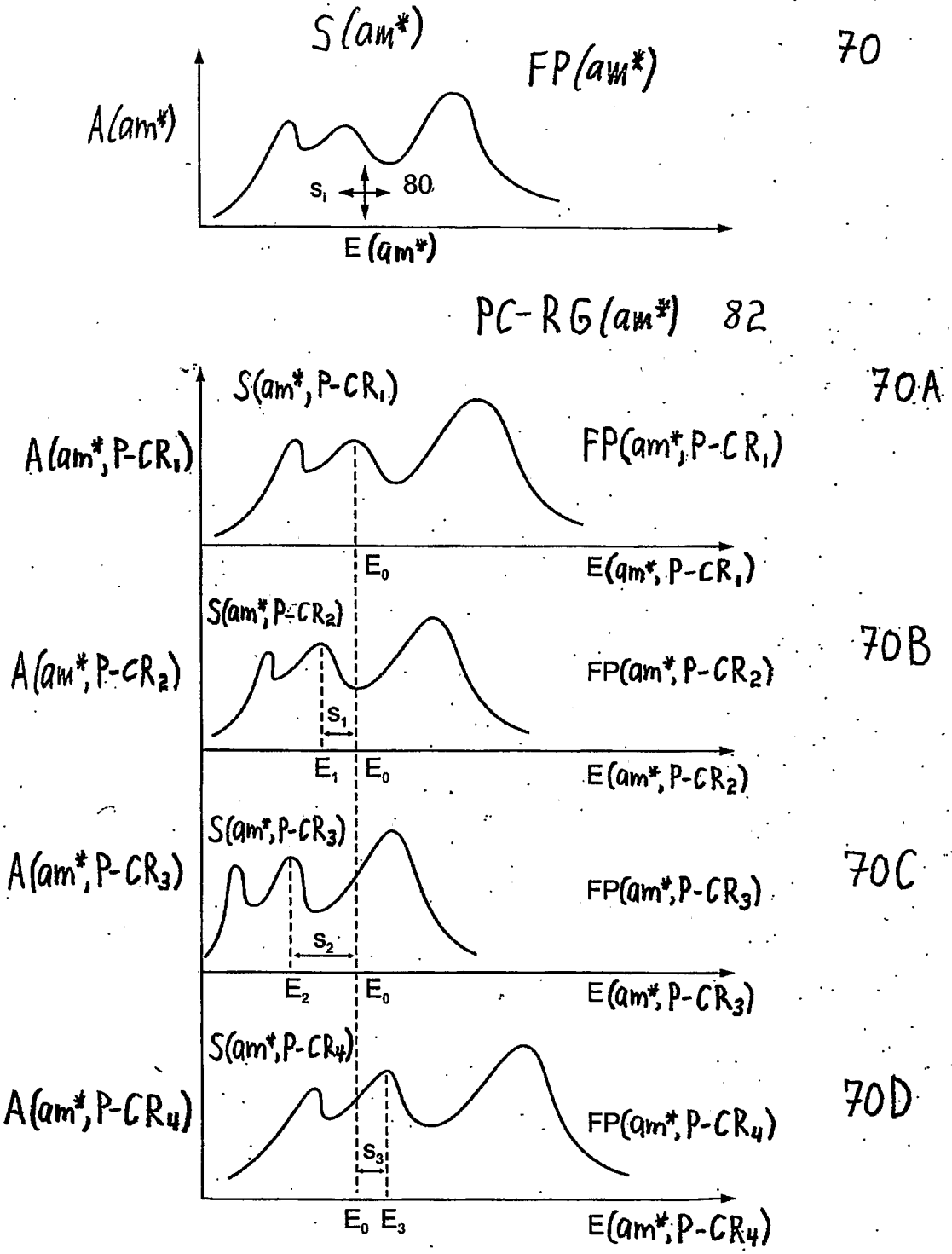
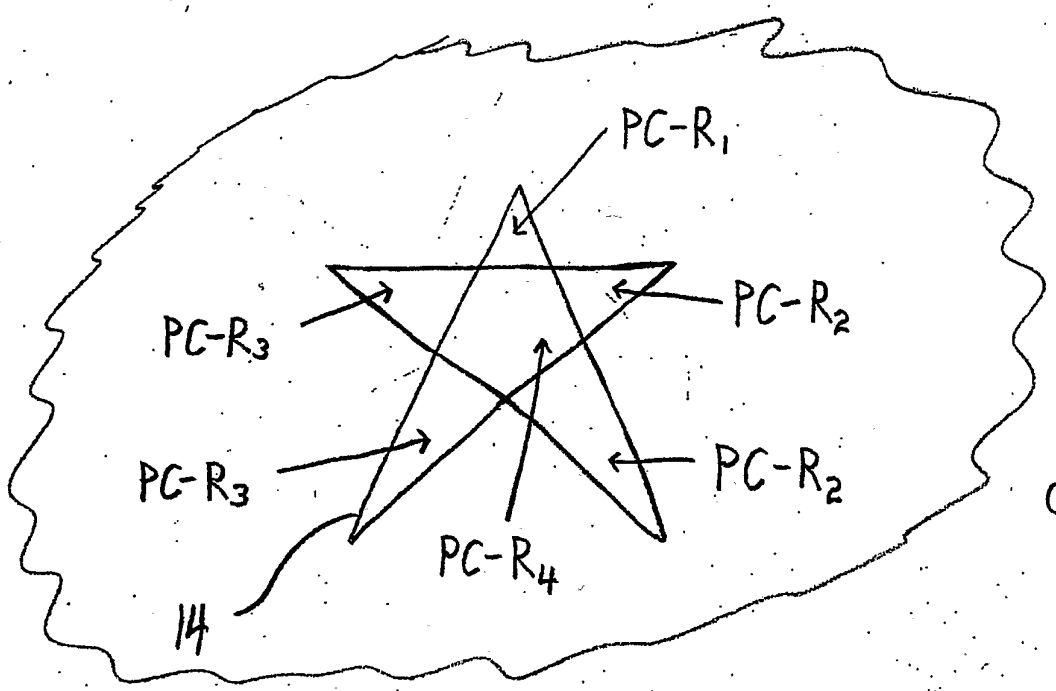

S(am*)
FP(am*)
70
A(am*)
S1
80
E(am*)
PC-RG(am*) 82
S(am*, P-CR1)
70A
A(am*, P-CR1)
FP(am*, P-CR1)
E0
E(am*, P-CR1)
S(am*, P-CR2)
70B
A(am*, P-CR2)
FP(am*, P-CR2)
S1
E1
E0
E(am*, P-CR2)
S(am*, P-CR3)
A(am*, P-CR3)
70C
FP(am*, P-CR3)
S2
E2
E0
E(am*, P-CR3)
S(am*, P-CR4)
A(am*, P-CR4)
70D
FP(am*, P-CR4)
S3
E0
E3
E(am*, P-CR4)

FIG. 2

PPCD[am*: PC-R_1(ppcd$_1$); PC-R_2(ppcd$_2$); PC-R_3(ppcd$_3$); PC-R_4(ppcd$_4$)]

90



PPCD Map[am*]

92

FIG. 3